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13. ABSTRACT *(Maximum 200 words)*
This TOP describes methods for measuring torque in tracked and wheeled vehicle power trains.

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Strain Gage	Power Losses
Slip Ring	Rotational Speed

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure (TOP) 2-2-806 30 December 1994
AD No.

POWER TRAIN TORQUE MEASUREMENTS

1. SCOPE. This TOP describes methods for measuring torque in tracked and wheeled vehicle power trains. Included are descriptions of the necessary vehicle preoperational preparations and procedures for the measurements of the transmission, drive shaft, and final drive torques, track (as applicable) and suspension power losses, and the overall power train efficiency under a full range of operating conditions.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Rated payloads	Simulated or actual
Equipment for drilling, milling, sanding, honing, and undercutting	For installation of strain gages/transmitters onto rotating shafts
Signal receiving station, such as a data van equipped with a data acquisition system (if data are transmitted via a telemetry system)	Means of receiving a data stream from a telemetry-based system

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Item	Requirement
Mobile dynamometer	Used for measuring drawbar pull and towing resistance
Torque calibration beam system (fabricated, to attach to instrumented shaft(s))	Used for shaft strain/torque calibration (measurements of ±0.1% of force applied and ±2 mm of beam length are required)

2.2 Instrumentation.

Devices for Measuring	Measurement Accuracy
Force (e.g., load cell)	±1.0% of reading
Vehicle speed (e.g., fifth wheel system)	±0.2 km/hr
Shaft speed (e.g., magnetic pickup)	±1.0 rpm
Strain (e.g., slip ring transducer/FM receiver system)	±2% of reading (overall system error)

3. REQUIRED TEST CONDITIONS.

3.1 Test Item. The following preparations must be made to the vehicle for testing, unless an "as received" test condition is specified:

a. Prepare the engine, transmission, and final drives of the test item for maximum performance by ensuring all adjustments are within the manufacturer's specifications.

b. If possible, obtain a laboratory engine performance calibration with and without engine accessories installed (e.g., auxiliary hydraulic pumps and alternators), using applicable portions of TOP 2-2-700[1**]. The bare engine measurements will be used to ensure that the required power specifications have been met before initiating the drive line torque field measurements.

c. Check all external adjustments, such as throttle linkage travel, track tension (if applicable), and brake adjustment. The track tension must be maintained throughout the field testing due to the critical effect of track tension on suspension power loss measurements.

d. Ensure that all lubricants are of the proper amount type and viscosity.

e. Unless otherwise specified, load the test item to its rated combat payload using actual or simulated weight items, so as to achieve a weight distribution and center of gravity which match the combat loading plan as

**Superscript numbers correspond to those in Appendix B, References.

closely as possible.

f. Record the following for the test item:

(1) Nomenclature.

(2) Model and end item serial numbers.

(3) Manufacturer.

(4) All pretest measurements and adjustments.

(5) Data collected per TOP 2-2-700 during laboratory engine performance calibration (if performed).

(6) Type and amounts of lubricants required/installed.

(7) Weight and center of gravity location of the payloaded test item.

3.2 Instrumentation Setup and Calibration. The measurement of shaft torque during vehicle field testing is typically performed using strain gages affixed to the shaft(s), with the strain signal either transmitted through wires and a slip ring setup or through an FM transmitter/antenna to a remote data acquisition system. Strain gages are typically mounted to the final drive output shafts (tracked vehicles) and to the transmission input and/or output shafts, depending on the extent of power train efficiency information desired (input torques are required if other than overall drive train performance measurement is desired).

The shafts are prepared for torque measurement as follows:

a. If the strain gage signals are to be transmitted through wires to a slip ring installation, the shafts must be drilled or milled as necessary to allow clearance for the wires to pass to a convenient point for the slip ring installation. Use of an FM transmitter system may eliminate a portion of the required machine work by permitting the transmitter to be clamped to an exposed portion of the shaft; however, the shaft surface must be sanded or honed in either case for the installation of the strain gages. Figure 1 shows an FM transmitter system installed to measure the drive shaft (transmission output) torque of a tactical vehicle.

b. Strain gages are installed at angles of 45° to the shaft longitudinal axis, since this is the maximum strain axis for a shaft in torsion. Consideration must be given to the strain gage location on the shaft, to avoid end effect or stress riser inputs to the measured strains, and care must be taken to ensure that the installation of the strain measurement system does not change the shaft's natural frequency or damping characteristics.

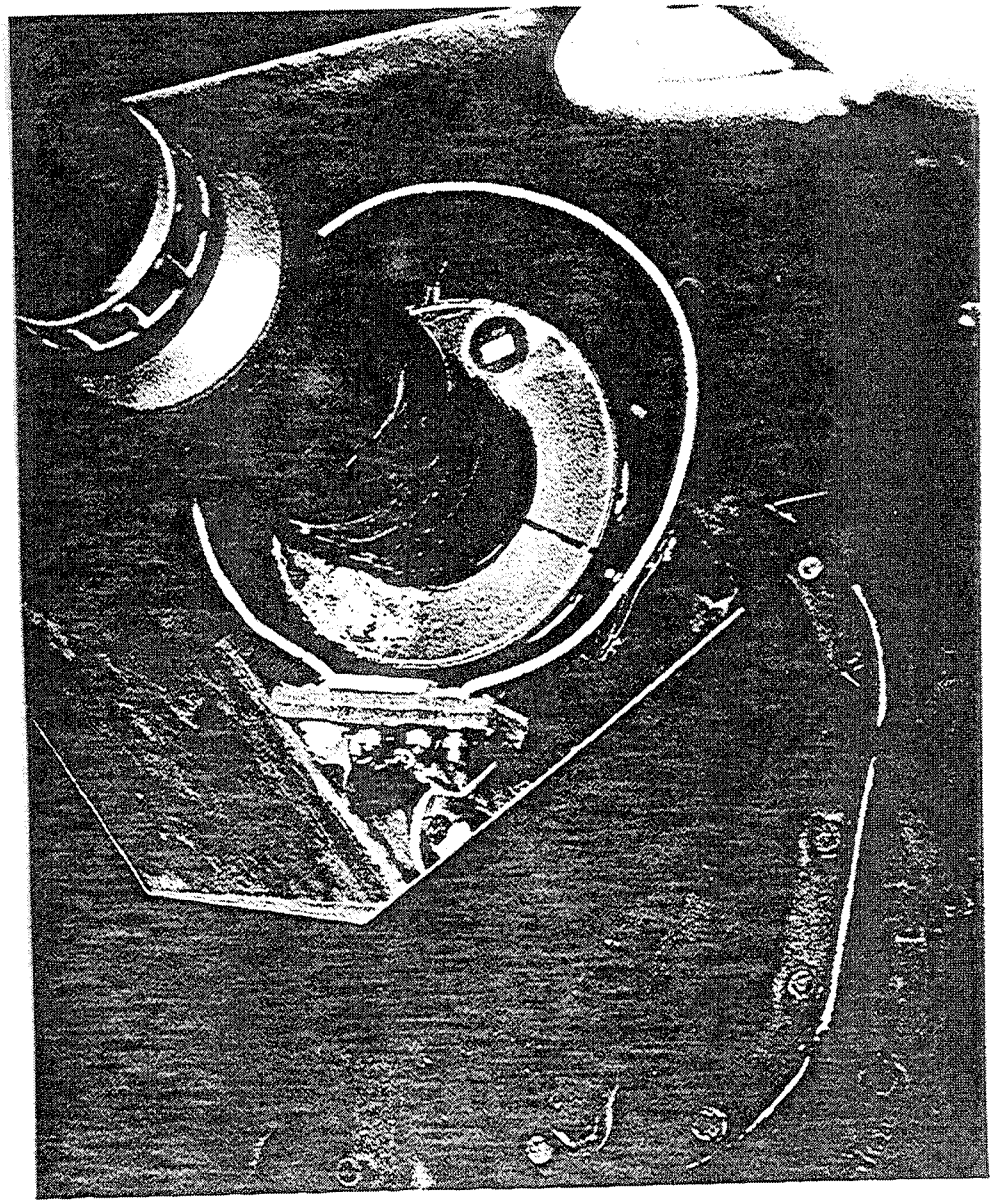

Figure 1. Typical FM transmitter system drive shaft installation.

c. The remainder of the measurement system (i.e., the data recording device) is then installed. This step is required prior to calibration to permit a full-system comparison of torque and strain.

d. Following the installation of the strain gage and transmitter system, the system must be electrically and physically calibrated, to determine the

exact relationship between shaft torque and the measured strain. This is best performed through the use of a fabricated calibration beam, where a measured force can be applied tangentially to the end of a beam of known length, which is attached to the instrumented shaft.

4. TEST PROCEDURES. The final drive output and transmission input and output torques (as required) are measured as follows:

a. Conduct drawbar pull test as described in ITOP 2-2-604(1)[2]/ITOP 2-2-604(3)[3]/TOP 2-2-604[4] as applicable.

b. Conduct gradeability tests on hard-surfaced slopes as described in ITOP 2-2-610(1)[5]/TOP 2-2-610[6] as applicable.

c. Conduct part-throttle operation at sustained speeds over as much of the test item's speed range as possible on level, hard-surfaced terrain. These tests must be repeated on soft-terrain media, such as tilled sand or sandy loam, if the item under test is an off-road vehicle and a determination of the power loss effects of soft soils is required. If these measurements are performed, the moisture level and soil Rating Cone Index (RCI) of the test site must be determined through the use of a soil trafficability test set, as described in ITOP 2-2-619(1)[7]/TOP 2-2-619[8] as applicable.

d. Conduct braking tests on level, hard-surfaced terrain as described in ITOP 2-2-627(1)[9]/TOP 2-2-608[10] as applicable.

e. Conduct towing resistance tests on level hard-surfaced terrain as described in ITOP 2-2-605(1)[11]/TOP 2-2-605[12].

5. DATA REQUIRED.

a. Transmission input and output torques.

b. Final drive output torque.

c. Shaft rotational speeds.

d. Engine speed.

e. Other relevant data as required.

Note: Power losses as determined through force or torque measurements are typically converted to power units, since engines are generally rated by power. Power is obtained from shaft speed and torque data through the relationship:

$$\text{Power (kW)} = \frac{\text{Shaft rotating speed (rpm) x torque (N·m)}}{2888}$$

6. PRESENTATION OF DATA. Data obtained may be presented as bar graphs, curves, or in tabulated form. Curves as shown in Appendix A are the most effective graphic presentation.

APPENDIX A. SAMPLE GRAPHIC PRESENTATIONS FOR TORQUE MEASUREMENT DATA

Vehicle:
Engine:
Transmission:

Track:
Vehicle Weight:
Date of Test:

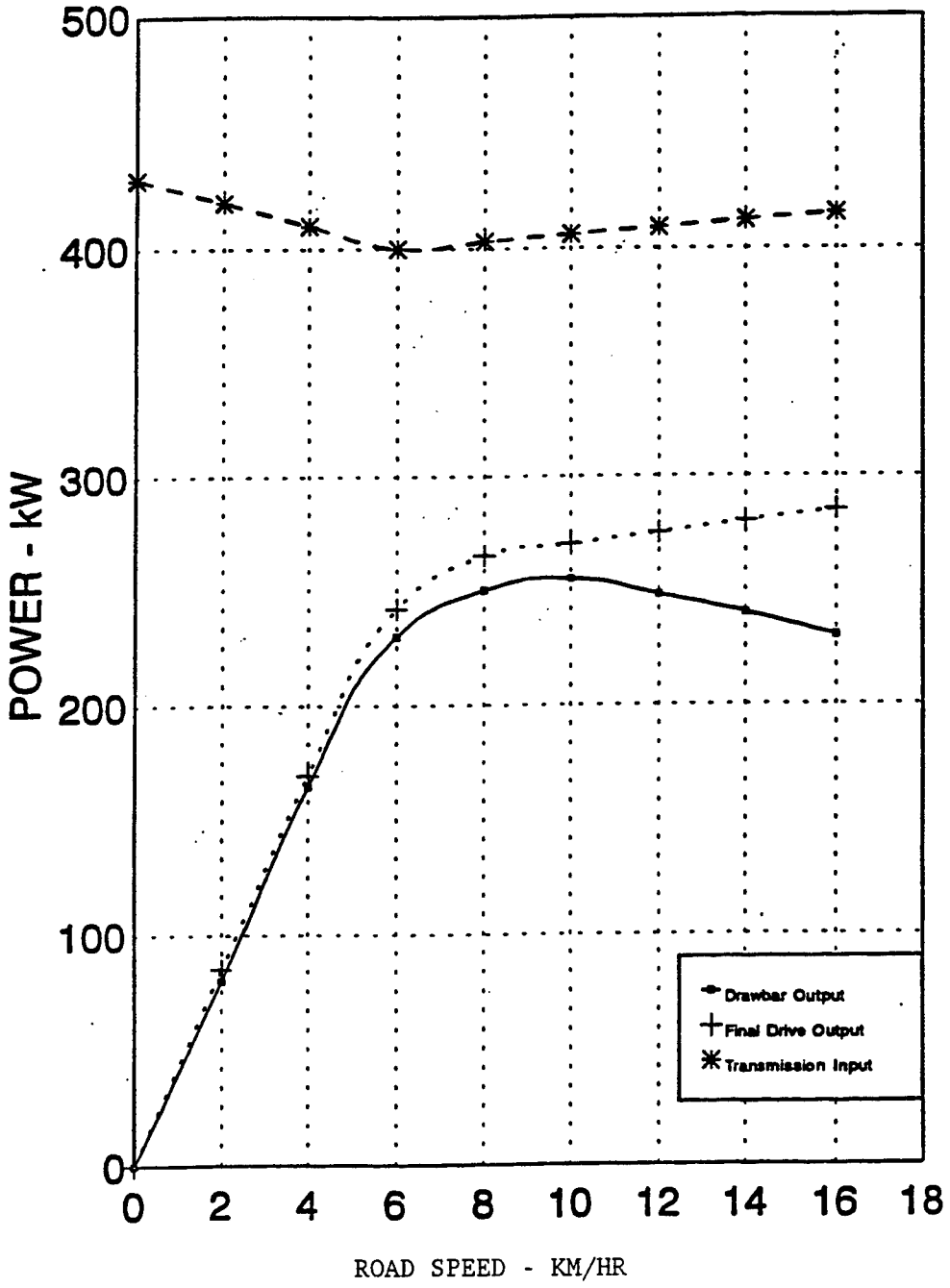

Figure A-1. Full-load power characteristics.

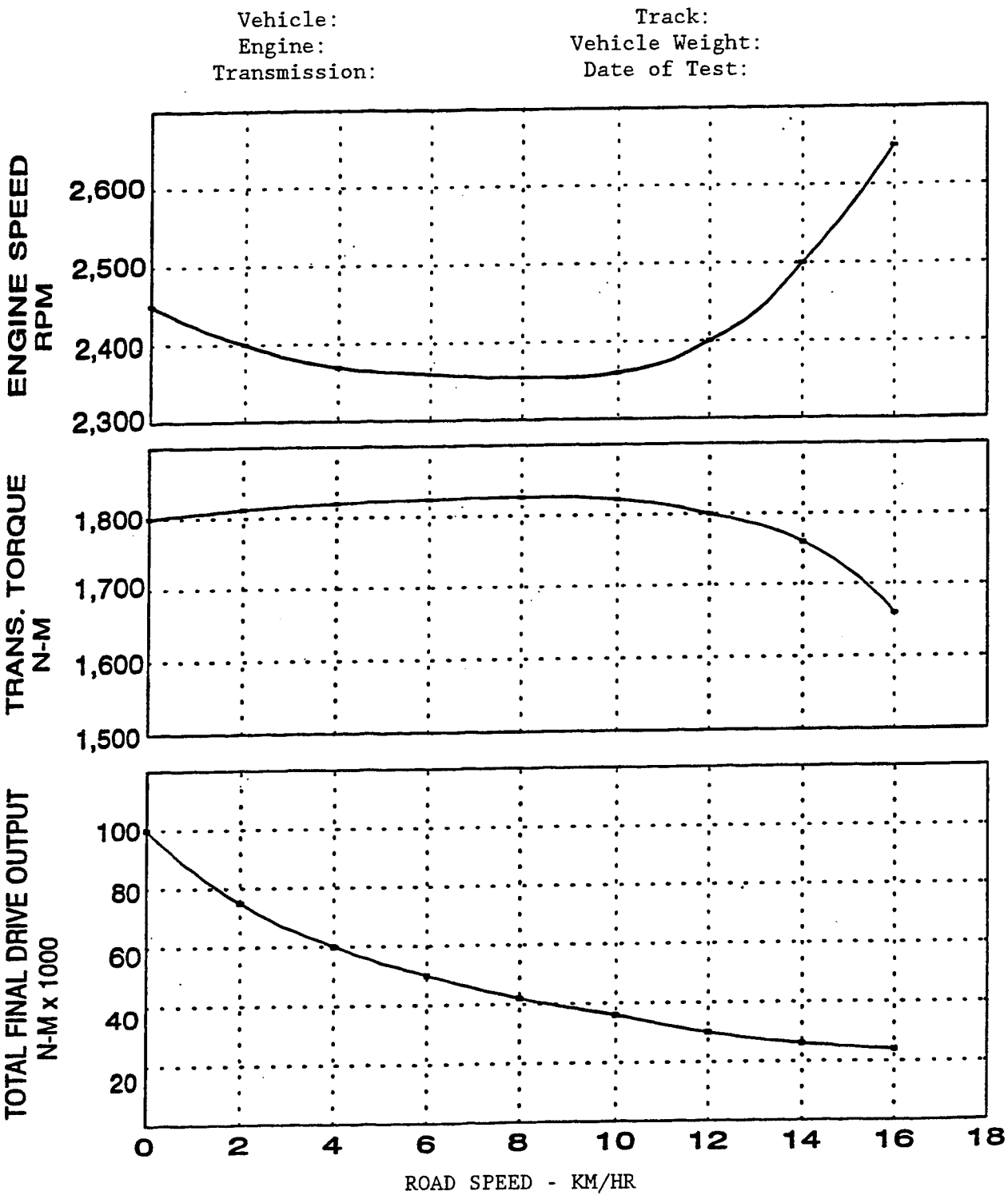

Figure A-2. Full-load torque characteristics.

APPENDIX B. REFERENCES

1. TECOM TOP 2-2-700, Laboratory Tests of Reciprocating Internal Combustion Engines, 24 January 1985.

2. FR/GE/UK/US ITOP 2-2-604(1), Tracked Vehicle Drawbar Pull on Soft Soil, 9 March 1987 w/change 1, 11 August 1987.

3. FR/GE/UK/US ITOP 2-2-604(3), Tracked Vehicle Drawbar Pull on Hard Surfaces, 21 May 1987.

4. TECOM TOP 2-2-604, Drawbar Pull, 18 July 1980.

5. FR/GE/UK/US ITOP 2-2-610(1), Tracked Vehicle Gradeability and Side-Slope Performance, 21 May 1987.

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7. FR/GE/UK/US ITOP 2-2-619(1), Tracked Vehicle Soft Soil Mobility, 1 June 1987.

8. TECOM TOP 2-2-619, Soft-Soil Vehicle Mobility, 21 May 1970.

9. FR/GE/UK/US ITOP 2-2-627(1), Tracked Vehicle Braking, 21 May 1987.

10. TECOM TOP 2-2-608, Braking, Wheeled Vehicles, 15 January 1971 w/change 1, 5 November 1982 & change 2, 24 June 1983.

11. FR/GE/UK/US ITOP 2-2-605(1), Tracked Vehicle Towing Resistance, 13 March 1987.

12. TECOM TOP 2-2-605, Wheeled Vehicle Towing Resistance, 29 July 1993.

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